SYMBOLS, SIGNS, AND ABBREVIATIONS

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THE SYMBOLS COMMITTEE OF
THE ROYAL SOCIETY

REPRESENTING

THE ROYAL SOCIETY
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FOREWORD

Since the publication in 1951 of the last Report of the Symbols Committee of the Royal Society considerable progress has been made towards international agreement on the names and symbols for physical quantities, on the definitions, names, and symbols for units, and on the rules for the expression of relations involving numbers between physical quantities and units.

The recommendations of the following international bodies, on each of which the U.K. is represented, are in virtually complete agreement wherever they overlap:

The General Conference on Weights and Measures
The International Organization for Standardization
The International Union of Pure and Applied Physics
The International Union of Pure and Applied Chemistry
The International Electrotechnical Commission

The British Standard B.S. 1991, Part 1, second edition, 1967, is also in virtually complete agreement with the international recommendations.

This new version of the Report of the Symbols Committee thus recommends for use in the publications of the four Societies the procedures and symbols which have been internationally agreed.

PART I

PHYSICAL QUANTITIES, UNITS, AND NUMERICAL VALUES

I.1. Introduction

The value of a *physical quantity* is equal to the product of a *numerical value* and a *unit*:

$$\text{physical quantity} = \text{numerical value} \times \text{unit}$$

Neither any physical quantity, nor the symbol used to denote it, should imply a particular choice of unit.

Operations on equations involving physical quantities, units, and numerical values, should follow the ordinary rules of algebra.

Thus the physical quantity called the wave length λ of one of the yellow sodium lines has the value:

$$\lambda = 5896\ \text{Å}$$

where Å is the symbol for the unit of length called the ångström (see §I.3). This may equally well be written in the form:

$$\lambda/\text{Å} = 5896$$

or in any of the other ways of expressing the equality of λ and 5896 multiplied by Å. By definition (see §I.3):

$$\text{Å} = 10^{-10}\,\text{m}$$

and

$$\text{in} = 2.54 \times 10^{-2}\,\text{m}$$

where m and in are the symbols for the units of length called respectively the metre and the inch; it follows that

$$\lambda/\text{m} = (\lambda/\text{Å}) \times (\text{Å}/\text{m}) = 5896 \times 10^{-10} = 5.896 \times 10^{-7}$$

and

$$\lambda/\text{in} = (\lambda/\text{m}) \times (\text{m}/\text{in}) = 5.896 \times 10^{-7}/2.54 \times 10^{-2} = 2.321 \times 10^{-5}$$

Thus λ may be equated to 5896 Å, or to 5.896×10^{-7} m, or to 2.321×10^{-5} in, but may not be equated to 5896 or to any other number.

For many dimensionless physical quantities the unit has no name or symbol and is not explicitly indicated (but see §I.3.4).

It follows from the above discussion that the expression which is placed at the head of a column of numerical values of a physical quantity in a table should be a pure number, such as the quotient of the symbol for the physical quantity and the symbol for the unit used.

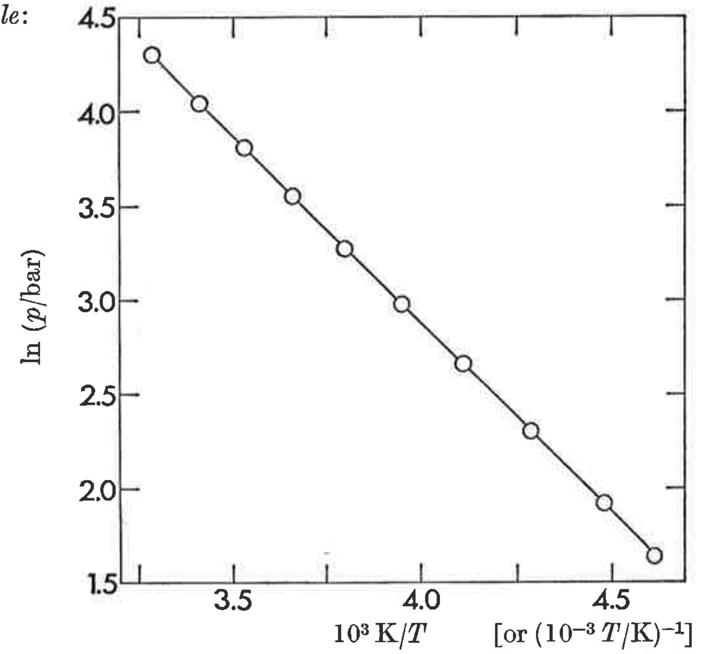
Example:

$\theta/°\text{C}$	T/K	$10^3\,\text{K}/T$	p/bar	$\ln(p/\text{bar})$	$V_\text{m}^\text{G}/\text{cm}^3\,\text{mol}^{-1}$	pV_m^G/RT
−56.60	216.55	4.6179	5.180	1.6448	3177.6	0.9142
0.00	273.15	3.6610	34.853	3.5511	456.97	0.7013
31.04	304.19	3.2874	73.815	4.3016	94.060	0.2745

An expression such as 'T(K)' where T denotes thermodynamic temperature means T multiplied by K. The convention that it has stood for T expressed in K should be abandoned in favour of T/K.

Similarly, the expression used to define the numerical values of a physical quantity plotted on a graph should be a pure number, such as the quotient of the symbol for the physical quantity and the symbol for the unit used.

Example:



A clear distinction should be drawn between physical quantities and units, and between the symbols for physical quantities and the symbols for units.

Symbols for physical quantities should be printed in italic (sloping) type. Symbols for units should be printed in roman (upright) type. In typescript the distinction should be made by underlining symbols for physical quantities in accord with standard printers' practice.

Physical quantities and the symbols for physical quantities are dealt with in §I.2. The symbols for physical quantities specified there are recommendations.

Units and symbols for units are dealt with in §I.3. The symbols for units specified there are mandatory.

Numbers are dealt with in §I.4.

I.2. Physical quantities and symbols for physical quantities

I.2.1. *Physical quantities*

A physical quantity is defined by a complete specification of the operations used to measure the ratio (a pure number) of two particular values of that physical quantity.

Each physical quantity is given a name and a symbol which is an abbreviation for that name.

I.2.2. *Symbols for physical quantities*

The symbol for a physical quantity should be a single letter of the latin or the greek alphabet.

An exception to this rule has been made for certain dimensionless quantities used in the study of transport processes, for which the internationally agreed symbols consist of two letters, the first a capital and the second lower case. Such two-letter symbols should be enclosed in parentheses. *Example*: Reynolds number: (Re).

When necessary the symbol for a physical quantity may be modified by attaching to it subscripts and/or superscripts and/or other modifying signs having specified meanings.

I.2.3. *Printing of symbols for physical quantities*

When letters of the latin alphabet are used as symbols for physical quantities they should be printed in italic type. When letters of the greek alphabet are used as symbols for physical quantities they should whenever possible be printed in sloping ('italic') rather than upright ('roman') type.

The symbols for vector quantities should be printed in bold faced italic type. *Examples*: force: $\boldsymbol{F}$, electric field strength: $\boldsymbol{E}$. (When the directional character of such quantities is not to be emphasized the use of ordinary italic type remains as an alternative. However, the use of bold faced italic type will often remain convenient in order to allow the use of the same letters for other quantities.)

A permissive variation, *though one not recommended by international authorities*, is the use of bold faced italic type for general physical constants.

The symbols for tensors of the second rank should be printed in bold faced sans serif type which whenever possible should be italic (sloping) rather than roman (upright). *Examples*: $\boldsymbol{\mathsf{S}}$, $\boldsymbol{\mathsf{T}}$.

Abbreviations, i.e. shortened forms of names such as p.f. for partition function, should not be used in mathematical equations. When used in text they should be printed in roman (upright) type. (See also Part VIII.)

I.2.4. *Choice of symbols for physical quantities*

A list of recommended symbols for physical quantities is given in §I.2.12. Whenever possible the symbol used for a physical quantity should be that (or one of those) recommended there.

Even with the use of both capital and lower case letters, and of bold faced as well as ordinary italic (sloping) type as specified in §I.2.3, the available distinctive letter symbols are insufficient to enable each symbol to be allotted to a single quantity. Some alternatives are therefore given in the list in §I.2.12 where a need for them is most likely to arise or, occasionally, where alternative usages are firmly established and unobjectionable. In some instances a preference is expressed (see heading of §I.2.12) and the preferred symbol should then be used whenever possible; in others no preference is expressed.

Where it is necessary to choose from alternative symbols for a quantity, or to adopt a symbol for a quantity not listed in §I.2.12, consideration should be given to current practice by authorities in the field and to the desirability that symbols for quantities constituting a well defined class should as far as possible belong to the same alphabet, fount, and case.

In order to obtain additional flexibility, capital letters may be used as variants for lower case letters, and vice versa, if no ambiguity is likely to arise. For example, instead of d_i and d_e for internal and external diameter, d and D may be used. The recommended symbol for length is l and for inductance L, but l and L may also be used for two lengths or two inductances; if length and inductance appear together, however, l should be used only for length and L for inductance, and necessary distinctions between different lengths or between different inductances should be made by means of subscripts or other modifying signs.

I.2.5. *Modifying signs*

Letter symbols, numbers, or other signs, may be placed as subscripts or superscripts immediately after the symbol for a physical quantity in order to modify its meaning. A list of recommended symbols for some of the most commonly needed subscripts and superscripts is given in §I.2.11.

For the use of other subscripts and superscripts, and of other modifying signs, no rigid rules are laid down but a satisfactory notation should fulfil the following requirements:

(i) it should be unambiguous;
(ii) it should be simple, systematic, and easy to remember;
(iii) it should not use more letters than necessary;
(iv) it should not be too expensive or difficult to print.

Modifying signs such as dots, bars, or tildes ($\sim$) may be placed above (or exceptionally below) the symbol for a physical quantity. Such signs, however, should be used sparingly and should never be letters of the alphabet or numbers.

Brackets, including parentheses ( ), braces { }, square brackets [ ], and angle brackets ⟨ ⟩, should not be used around the symbol for a quantity in order to make it represent any other quantity, unless such use is consistently adopted for a whole class of quantities as in crystallography. In particular, the use of square brackets around a chemical formula to denote the concentration of the substance is recommended.

I.2.6. *Printing of subscripts and superscripts*

Subscripts or superscripts which are themselves symbols for physical quantities should be printed in italic (sloping) type. All other letter symbols used as subscripts or superscripts should be printed in roman (upright) type.

Example: C_p for heat capacity at constant pressure, but
C_{B} for heat capacity of substance B

When two or more subscripts, or two or more superscripts, having separate meanings are attached to the same symbol they should be separated by commas.

Example: $C_{p,\mathrm{B}}$ for heat capacity at constant pressure of substance B

Second-order superscripts or subscripts should be avoided as far as possible. Thus e^{x^2} may be printed as $\exp x^2$. Also $\Lambda_{\mathrm{NO}_3^-}$ may be printed as $\Lambda(\mathrm{NO}_3^-)$ and $\rho_{20\,^\circ\mathrm{C}}$ as $\rho(20\,^\circ\mathrm{C})$.

I.2.7. *Basic physical quantities*

Seven physical quantities are chosen as *basic physical quantities*:

Basic physical quantity	Symbol for quantity
length	l
mass	m
time	t
electric current	I
thermodynamic temperature	T
amount of substance	n
luminous intensity	I_{v}

I.2.8. *Derived physical quantities*

All other physical quantities are regarded as being derived from the basic physical quantities.

I.2.9. *Use of the words 'specific' and 'molar'*

The word 'specific' before the name of an extensive physical quantity is restricted to the meaning 'divided by mass'. For example, specific volume is the volume divided by the mass. When the extensive quantity is represented by a capital letter, the corresponding specific quantity may be represented by the corresponding lower case letter.

Examples: volume: V specific volume: $v = V/m$
heat capacity: C_p specific heat capacity: $c_p = C_p/m$

The numerical value of a specific physical quantity depends on the units selected for the physical quantity and for the mass.

The word 'molar' before the name of an extensive quantity is restricted to the meaning 'divided by amount of substance'. For example, molar volume is the volume divided by the amount of substance. The subscript m attached to the symbol for the extensive quantity denotes the corresponding molar quantity.

Examples: volume: V molar volume: $V_{\mathrm{m}} = V/n$
Gibbs function: G molar Gibbs function: $G_{\mathrm{m}} = G/n$

The subscript m may be omitted where there is no risk of ambiguity.

The numerical value of a molar physical quantity depends on the units selected for the physical quantity and for the amount of substance. The most commonly used unit for amount of substance is the mole (see §I.3.2).

I.2.10. *Partial molar quantities*

The symbol X_{B}, where X denotes an extensive quantity and B is the chemical symbol for a substance, denotes the partial molar quantity for the substance B defined by the relation:

$$X_{\mathrm{B}} = (\partial X/\partial n_{\mathrm{B}})_{T,p,n_{\mathrm{C}},\ldots}$$

The partial molar quantity X_{B} for a pure substance B, which is identical with the molar quantity X_{m} for the pure substance B, may be denoted by $X_{\mathrm{B}}^{\bullet}$, where the superscript $^{\bullet}$ denotes 'pure', so as to distinguish it from the partial molar quantity X_{B} for the substance B in a mixture.

I.2.11. *List of recommended subscripts and superscripts and other modifying signs to be used with the symbols for physical quantities*

(*a*) *Subscripts*

I, II … 1, 2 …	*especially with symbols for thermodynamic functions*, referring to different systems or different states of a system
A, B …	referring to molecular species A, B, etc.
i	referring to a typical ionic species i
u	referring to an undissociated molecule
p, V, T, S etc.	indicating constant pressure, volume, temperature, entropy etc.
p, m, c, a	*with symbol for an equilibrium constant*, indicating that it is expressed in terms of pressure, molality, concentration, or relative activity
G, L, S, X	referring to gas, liquid, solid, and crystalline states respectively
f, e, s, t, d	referring to fusion, evaporation, sublimation, transition, and dissolution or dilution respectively
c	referring to the critical state or indicating a critical value
C, D, F	*with symbols for optical properties*, referring to particular wave lengths.
+, −	referring to a positive or negative ion, or to a positive or negative electrode
∞	indicating limiting value at infinite dilution.

Some of the above subscripts may sometimes be more conveniently used as superscripts.

(*b*) *Superscripts*

$^\ominus$	standard in general
$^\bullet$	indicating a pure substance
$^{\mathrm{id}}$	ideal
$^{\mathrm{E}}$	excess

I.2.12. *List of recommended symbols for physical quantities*

It is recognized that according to context some departures from the recommended symbols will be necessary. Where two or more symbols separated by commas are given for a quantity, these symbols are regarded as alternatives for which no preference is expressed; where they are separated by a dotted line, the first is preferred.

[*Note*: A, B denotes no preference; $A\ldots B$ denotes A preferred]

(*a*) Space and time

angle (plane angle)	$\alpha, \beta, \gamma, \theta, \phi$, etc.	spherical coordinates	r, θ, ϕ
solid angle	Ω, ω	position vector (radius vector)	$\boldsymbol{r}$
length	l	area	$A\ldots S$
breadth	b	volume	$V\ldots v$
height	h	time	t
thickness	d, δ	angular velocity: $\mathrm{d}\theta/\mathrm{d}t$	ω
radius	r	angular acceleration: $\mathrm{d}\omega/\mathrm{d}t$	α
diameter: $2r$	d	velocity: $\mathrm{d}s/\mathrm{d}t$	u, v, w
distance along path	s, L	acceleration: $\mathrm{d}u/\mathrm{d}t$	a
generalized coordinate	q	acceleration of free fall	g
rectangular coordinates	x, y, z	speed of light in a vacuum	c
cylindrical coordinates	r, ϕ, z	Mach number	(Ma)

(*b*) Periodic and related phenomena

period	T	circular wave number: $2\pi\sigma$	k
relaxation time (1)	τ	circular wave vector	$\boldsymbol{k}$
frequency: $1/T$	ν, f	damping coefficient (3)	δ
rotational frequency	n	logarithmic decrement (3): δ/ν	Λ
angular frequency (2): $2\pi\nu$	ω	attenuation coefficient (4)	α
wave length	λ	phase coefficient (4)	β
wave number : $1/\lambda$	$\sigma\ldots\tilde{\nu}$	propagation coefficient (4): $\alpha + \mathrm{i}\beta$	γ
wave vector	$\boldsymbol{\sigma}$		

(1) If F is a function of time t given by $F(t) = A + B\exp(-t/\tau)$. τ is also called time constant.
(2) Also called pulsatance.
(3) When F is a function of time t given by $F(t) = A\exp(-\delta t)\sin\{2\pi\nu(t-t_0)\}$.
(4) When F is a function of distance x given by $F(x) = A\exp(-\alpha x)\cos\{\beta(x-x_0)\}$.

[*Note*: A, B denotes no preference; $A\ldots B$ denotes A preferred]

(*c*) Mechanics

mass	m	shear modulus: τ/γ	G
density (mass density): m/V	ρ	bulk modulus: $-p/\theta$	K
relative density: ρ_2/ρ_1	d	Poisson ratio	μ, ν
specific volume: V/m	v	compressibility: $-V^{-1}\mathrm{d}V/\mathrm{d}p$	κ
reduced mass: $m_1 m_2/(m_1+m_2)$	μ	second moment of area (2)	I_a
momentum: mu	p	second polar moment of area (3)	I_p
momentum (vector): $m\boldsymbol{u}$	$\boldsymbol{p}$	section modulus	Z, W
angular momentum	b, p_θ	coefficient of friction	$\mu\ldots f$
angular momentum (vector): $\boldsymbol{r}\times\boldsymbol{p}$	$\boldsymbol{L}$	viscosity (dynamic viscosity)	$\eta\ldots\mu$
moment of inertia (1)	I, J	fluidity: $1/\eta$	ϕ
force	F	kinematic viscosity: η/ρ	ν
force (vector)	$\boldsymbol{F}$	diffusion coefficient	D
weight	$G\ldots P, W$	surface tension	γ, σ
bending moment	M	angle of contact	θ
moment of force (vector): $\boldsymbol{r}\times\boldsymbol{F}$	$\boldsymbol{M}$	work	W, A
torque, moment of a couple	$\boldsymbol{T}$	energy	E, W
pressure	$p\ldots P$	potential energy	E_{p}, V, Φ
normal stress	σ	kinetic energy	E_{k}, T, K
shear stress	τ	power	P
linear strain: $\Delta l/l_0$	ϵ, e	Hamiltonian function	H
shear strain (shear angle): $\Delta\theta/\theta_0$	γ	Lagrangian function	L
volume strain: $\Delta V/V_0$	θ	gravitational constant	G
Young modulus: σ/ϵ	E	Reynolds number: $\rho u l/\eta$	(Re)

(1) $I_z = \int(x^2+y^2)\,\mathrm{d}m$. (2) $I_{a,y} = \int x^2\,\mathrm{d}x\,\mathrm{d}y$. (3) $I_p = \int(x^2+y^2)\,\mathrm{d}x\,\mathrm{d}y$.

(*d*) Thermodynamics

thermodynamic temperature (absolute temperature)	$T\ldots\Theta$	specific heat capacity at constant volume	c_V
common temperature	t, θ	ratio c_p/c_V	γ, κ
linear expansivity: $l^{-1}\mathrm{d}l/\mathrm{d}T$	α, λ	thermal diffusivity: $\lambda/\rho c_p$	α
cubic expansivity: $V^{-1}\mathrm{d}V/\mathrm{d}T$	α, γ	entropy	S
heat, quantity of heat	q, Q	internal energy	$U\ldots E$
work, quantity of work	w, W	enthalpy: $U+pV$	H
heat flow rate	$\Phi\ldots q$	Helmholtz function: $U-TS$	$A\ldots F$
thermal conductivity	$\lambda\ldots k$	Gibbs function: $U+pV-TS$	G
heat capacity	C	Massieu function: $-A/T$	J
specific heat capacity: C/m	c	Planck function: $-G/T$	Y
specific heat capacity at constant pressure	c_p	specific entropy: S/m	s
		specific internal energy: U/m	$u\ldots e$

specific enthalpy: H/m	h
specific Helmholtz function: A/m	$a \ldots f$
specific Gibbs function: G/m	g
latent heat	L
specific latent heat: L/m	l
Joule–Thomson coefficient: $(\partial T/\partial P)_H$	μ, μ_{JT}

isothermal compressibility: $-V^{-1}(\partial V/\partial p)_T$	κ, κ_T
isentropic compressibility: $-V^{-1}(\partial V/\partial p)_S$	κ_S
isobaric expansivity: $V^{-1}(\partial V/\partial T)_p$	α
thermal diffusion ratio	k_T
thermal diffusion factor	α_T
thermal diffusion coefficient	D_T

(*e*) Electricity and magnetism

electric charge (quantity of electricity)	Q
electric current: $\mathrm{d}Q/\mathrm{d}t$	I
charge density: Q/V	ρ
surface charge density: Q/A	σ
electric field strength	$\boldsymbol{E}$
electric potential	V, ϕ
electric potential difference	$U \ldots V$
electromotive force	E
electric displacement	$\boldsymbol{D}$
electric flux	Ψ
capacitance	C
permittivity: $\boldsymbol{D} = \epsilon \boldsymbol{E}$	ϵ
permittivity of a vacuum	ϵ_0
relative permittivity (1): ϵ/ϵ_0	ϵ_{r}
electric susceptibility: $\epsilon_{\mathrm{r}} - 1$	χ_{e}
electric polarization: $\boldsymbol{D} - \epsilon_0 \boldsymbol{E}$	$\boldsymbol{P}$
electric dipole moment	$\boldsymbol{p} \ldots \boldsymbol{\mu}$
electric current density	$\boldsymbol{J}, \boldsymbol{j}$
magnetic field strength	$\boldsymbol{H}$
magnetic potential difference	U_{m}
magnetomotive force: $\oint H_s \mathrm{d}s$	F_{m}
magnetic flux density, magnetic induction	$\boldsymbol{B}$
magnetic flux	Φ
magnetic vector potential	$\boldsymbol{A}$
self inductance	L
mutual inductance	M, L_{12}
coupling coefficient: $L_{12}/(L_1 L_2)^{\frac{1}{2}}$	k
leakage coefficient: $(1 - k^2)$	σ
permeability	μ
permeability of a vacuum	μ_0

relative permeability: μ/μ_0	μ_{r}
magnetic susceptibility: $\mu_{\mathrm{r}} - 1$	χ_{m}
electromagnetic moment: $E_{\mathrm{p}} = -\boldsymbol{m} \cdot \boldsymbol{B}$	$\boldsymbol{m}$
magnetization: $\boldsymbol{B} = \mu_0(\boldsymbol{H} + \boldsymbol{M})$	$\boldsymbol{M}$
magnetic polarization: $\boldsymbol{B} - \mu_0 \boldsymbol{H}$	$\boldsymbol{J}$
electromagnetic energy density	w
Poynting vector: $\boldsymbol{E} \times \boldsymbol{H}$	$\boldsymbol{S}$
velocity of propagation of electromagnetic waves in vacuum	c
resistance	R
conductance: $1/R$	G
resistivity: $\boldsymbol{E}/\boldsymbol{J}$	ρ
conductivity: $1/\rho$	γ, σ
reluctance: U_{m}/Φ	R, R_{m}
permeance: $1/R_{\mathrm{m}}$	Λ
number of turns	N
number of phases	m
number of pairs of poles	p
loss angle	δ
phase displacement	ϕ
impedance: $R + \mathrm{i}X$	Z
reactance: $\mathrm{Im}\, Z$	X
resistance: $\mathrm{Re}\, Z$	R
quality factor: $\lvert X \rvert / R$	Q
admittance: $1/Z$	Y
susceptance: $\mathrm{Im}\, Y$	B
conductance: $\mathrm{Re}\, Y$	G
power, active	P
power, reactive	Q
power, apparent	S

(1) Also called dielectric constant, D, when it is independent of $\boldsymbol{E}$.

(*f*) Light and related electromagnetic radiation

The same symbol is often used for a pair of corresponding radiant and luminous quantities. Subscripts $_{\mathrm{e}}$ for radiant and $_{\mathrm{v}}$ for luminous may be used when necessary to distinguish these quantities.

velocity of electromagnetic waves in vacuum	c
radiant energy	Q, Q_{e}
radiant flux, radiant power	$\Phi, \Phi_{\mathrm{e}} \ldots P$
radiant intensity	I, I_{e}
radiance	L, L_{e}
radiant emittance	M, M_{e}
irradiance	E, E_{e}
emissivity	ϵ
quantity of light	Q, Q_{v}
luminous flux	Φ, Φ_{v}
luminous intensity	I, I_{v}
luminance	L, L_{v}
luminous emittance	M, M_{v}

illuminance, illumination	E, E_{v}
light exposure: $\int E\, \mathrm{d}t$	H
luminous efficacy: $\Phi_{\mathrm{v}}/\Phi_{\mathrm{e}}$	K
absorption factor, absorptance: Φ_{a}/Φ_0	α
reflexion factor, reflectance: Φ_{r}/Φ_0	ρ
transmission factor, transmittance: $\Phi_{\mathrm{tr}}/\Phi_0$	τ
linear extinction coefficient	μ
linear absorption coefficient	a
refractive index	n
refraction: $(n^2 - 1)\, V/(n^2 + 2)$	R
angle of optical rotation	α

(*g*) Acoustics

velocity of sound	c
velocity of longitudinal waves	c_{l}
velocity of transverse waves	c_{t}
group velocity	c_{g}
sound energy flux	P
sound intensity	I, J

reflexion coefficient: P_{r}/P_0	ρ
acoustic absorption coefficient: $(1 - \rho)$	$\alpha_{\mathrm{a}} \ldots \alpha$
transmission coefficient: P_{tr}/P_0	τ
dissipation coefficient: $(\alpha_{\mathrm{a}} - \tau)$	δ
loudness level	L_{N}

A more complete list of symbols for acoustic quantities is to be found in I.S.O. Recommendation R. 31, Part VII, 'Quantities and units of acoustics', November 1965, obtainable in the U.K. from the British Standards Institution.

(*h*) Physical chemistry

relative atomic mass of an element (atomic weight) (1)	A_{r}
relative molecular mass of a substance (molecular weight) (1)	M_{r}

amount of substance	n
molar mass: m/n	M
molar volume: V/n	V_{m}
molar internal energy: U/n	U_{m}

(1) The ratio of the average mass per atom (molecule) of the natural isotopic composition of an element (the elements) to 1/12 of the mass of an atom of the nuclide $^{12}\mathrm{C}$.

Examples: $A_{\mathrm{r}}(\mathrm{Cl}) = 35.453$ $M_{\mathrm{r}}(\mathrm{KCl}) = 75.401$

The concept of relative atomic or molecular mass may be extended to other specified isotopic compositions, but the natural isotopic composition is assumed unless some other composition is specified.

[*Note*: A, B denotes no preference; $A ... B$ denotes A preferred]

molar enthalpy: H/n	H_m
molar heat capacity: C/n	C_m
at constant pressure: C_p/n	$C_{p,\mathrm{m}}$
at constant volume: C_V/n	$C_{V,\mathrm{m}}$
molar entropy: S/n	S_m
molar Helmholtz function: A/n	A_m
molar Gibbs function: G/n	G_m
(molar) gas constant	R
compression factor: pV_m/RT	Z
mole fraction of substance B	x_B
mass fraction of substance B	w_B
volume fraction of substance B	ϕ_B
molality of solute B: (n_B divided by mass of solvent)	m_B
concentration (molarity) of solute B: n_B/V	c_B, [B]
chemical potential of substance B: $(\partial G/\partial n_\mathrm{B})_{T,p,n_\mathrm{C},\ldots}$	μ_B
absolute activity of substance B: $\exp(\mu_\mathrm{B}/RT)$	λ_B
partial pressure of substance B in a gas mixture: $x_\mathrm{B}^\mathrm{G}p$	p_B
fugacity of substance B in a gas mixture: $\lambda_\mathrm{B}\lim_{p\to 0}(x_\mathrm{B}^\mathrm{G}p/\lambda_\mathrm{B})$	p_B^*
relative activity of substance B	a_B
activity coefficient (mole fraction basis)	f_B
activity coefficient (molality basis)	γ_B
activity coefficient (concentration basis)	y_B
osmotic coefficient	g, ϕ
osmotic pressure	Π
surface concentration	Γ
electromotive force	E
Faraday constant	F
charge number of ion i	z_i
ionic strength: $\frac{1}{2}\Sigma_\mathrm{i} m_\mathrm{i} z_\mathrm{i}^2$	I
velocity of ion i	v_i

electric mobility of ion i: v_i/E	u_i
electrolytic conductivity ⁽¹⁾: J/E	κ
molar conductance of electrolyte: κ/c	Λ
transport number of ion i	t_i
molar conductance of ion i: $t_\mathrm{i}\Lambda$	λ_i
overpotential	η
exchange current density	j_0
electrokinetic potential	ζ
intensity of light	I
transmittance: I/I_0	T
absorption (extinction) coefficient: $(-\ln T)/lc_\mathrm{B}$	κ
absorbance (extinction) ⁽²⁾: $-\log_{10}T$	A
absorptivity (decadic absorption or extinction coefficient): A/l	a
molar absorptivity (molar decadic absorption or extinction coefficient): A/lc_B	ϵ
angle of optical rotation	α
specific optical rotatory power: $\alpha V/ml$	α_m
molar optical rotatory power: $\alpha/c_\mathrm{B}l$	α_n
molar refraction: $(n^2-1)V_\mathrm{m}/(n^2+2)$	R_m
stoichiometric coefficient of molecules B (negative for reactants, positive for products)	ν_B
general equation for a chemical reaction	$0 = \Sigma_\mathrm{B}\,\nu_\mathrm{B}\mathrm{B}$
affinity of a reaction: $-\Sigma_\mathrm{B}\nu_\mathrm{B}\mu_\mathrm{B}$	$\boldsymbol{A}$
equilibrium constant	K
degree of dissociation	α
extent of reaction: $\mathrm{d}\xi = \mathrm{d}n_\mathrm{B}/\nu_\mathrm{B}$	ξ
rate of reaction: $\mathrm{d}\xi/\mathrm{d}t$	$\dot{\xi}, J$
rate constant of a reaction	k
activation energy of a reaction	E

---

(1) Formerly called specific conductance.

(2) Formerly called optical density.

[*Note*: A, B denotes no preference; $A ... B$ denotes A preferred]

(*i*) Molecular physics

Avogadro constant	L, N_A
number of molecules	N
number density of molecules: N/V	n
molecular mass	m
molecular velocity	$\boldsymbol{c}(c_x, c_y, c_z)$, $\boldsymbol{u}(u_x, u_y, u_z)$
molecular position	$\boldsymbol{r}(x, y, z)$
molecular momentum	$\boldsymbol{p}(p_x, p_y, p_z)$
average velocity	$\langle \boldsymbol{c} \rangle, \langle \boldsymbol{u} \rangle, \boldsymbol{c}_0, \boldsymbol{u}_0$
average speed	$\langle c \rangle, \langle u \rangle, \bar{c}, \bar{u}$,
most probable speed	$\hat{c}, \hat{u}$
mean free path	l, λ
molecular attraction energy	ϵ
interaction energy between molecules i and j	$\phi_\mathrm{ij}, V_\mathrm{ij}$
velocity distribution function: $N/V = \int f \mathrm{d}c_x \mathrm{d}c_y \mathrm{d}c_z$	$f(c)$
Boltzmann function	H
generalized coordinate	q
generalized momentum	p
volume in phase space	Ω
Boltzmann constant	k

$1/kT$ in exponential functions	β
partition function	Q, Z
grand partition function	Ξ
statistical weight	g
symmetry number	σ, s
dipole moment of molecule	p, μ
quadrupole moment of molecule	Θ
polarizability of molecule	α
Planck constant	h
Planck constant divided by 2π	$\hbar$
characteristic temperature	Θ
Debye temperature: $h\nu_\mathrm{D}/k$	Θ_D
Einstein temperature: $h\nu_\mathrm{E}/k$	Θ_E
rotational temperature: $h^2/8\pi^2 Ik$	Θ_r
vibrational temperature: $h\nu/k$	Θ_v
Stefan–Boltzmann constant: $2\pi^5k^4/15c^2h^3$	σ
first radiation constant: $2\pi hc^2$	c_1
second radiation constant: hc/k	c_2
rotational quantum number	J, K
vibrational quantum number	v

(*j*) Atomic and nuclear physics

nucleon number, mass number	A
atomic number, proton number	Z
neutron number: $A-Z$	N
(rest) mass of atom	m_a
unified atomic mass constant: $m_\mathrm{a}(^{12}\mathrm{C})/12$	m_u
(rest) mass of electron	m_e
(rest) mass of proton	m_p
(rest) mass of neutron	m_n
elementary charge (of proton)	e
Planck constant	h
Planck constant divided by 2π	$\hbar$
Bohr radius: $h^2/\pi\mu_0 c^2 m_\mathrm{e} e^2$	a_0
Rydberg constant: $\mu_0^2 m_\mathrm{e} e^4 c^3/8h^3$	R_∞

magnetic moment of particle	μ
Bohr magneton: $eh/4\pi m_\mathrm{e}$	μ_B
nuclear magneton: $(m_\mathrm{e}/m_\mathrm{p})\mu_\mathrm{B}$	μ_N
gyromagnetic ratio: $2\pi\mu/Ih$	γ
g-factor	g
Larmor (angular) frequency: $e\boldsymbol{B}/2m_\mathrm{e}$	ω_L
nuclear angular precession frequency: $ge\boldsymbol{B}/2m_\mathrm{p}$	ω_N
cyclotron angular frequency of electron: $e\boldsymbol{B}/m_\mathrm{e}$	ω_c
nuclear quadrupole moment	Q
nuclear radius	R
orbital angular momentum quantum number	L, l

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

spin angular momentum quantum number	S, s_i
total angular momentum quantum number	J, j_i
nuclear spin quantum number	I, J
hyperfine structure quantum number	F
principal quantum number	n, n_i
magnetic quantum number	M, m_i
fine structure constant: $\mu_0 e^2 c/2h$	α
electron radius: $\mu_0 e^2/4\pi m_e$	r_e
Compton wave length: h/mc	λ_C

mass excess: $m_a - A m_u$	$\mathit{\Delta}$
packing fraction: $\mathit{\Delta}/A m_u$	f
mean life	τ
level width: $h/2\pi\tau$	$\mathit{\Gamma}$
activity: $-\mathrm{d}N/\mathrm{d}t$	A
specific activity: A/m	a
decay constant: A/N	λ
half-life: $(\ln 2)/\lambda$	$T_{\frac{1}{2}}, t_{\frac{1}{2}}$
disintegration energy	Q
spin-lattice relaxation time	T_1
spin-spin relaxation time	T_2
indirect spin-spin coupling	J

(*k*) Nuclear reactions and ionizing radiations

reaction energy	Q
cross section	σ
macroscopic cross section	$\mathit{\Sigma}$
impact parameter	b
scattering angle	θ, ϕ
internal conversion coefficient	α
linear attenuation coefficient	μ, μ_l

atomic attenuation coefficient	μ_a
mass attenuation coefficient	μ_m
linear stopping power	S, S_l
atomic stopping power	S_a
linear range	R, R_l
recombination coefficient	α

(*l*) Quantum mechanics

complex conjugate of $\mathit{\Psi}$	$\mathit{\Psi}^*$
probability density: $\mathit{\Psi}^*\mathit{\Psi}$	P
probability current density: $(h/2\pi i m)(\mathit{\Psi}^*\nabla\mathit{\Psi} - \mathit{\Psi}\nabla\mathit{\Psi}^*)$	$\boldsymbol{S}$
charge density of electrons: $-eP$	ρ
electric current density of electrons: $-e\boldsymbol{S}$	$\boldsymbol{j}$
expectation value of A	$\langle A \rangle, \bar{A}$
commutator of A and B: $AB - BA$	$[A, B], [A, B]_-$

anticommutator of A and B: $AB + BA$	$[A, B]_+$
matrix element: $\int \phi_i^*(A\phi_j)\,\mathrm{d}\tau$	A_{ij}
Hermitian conjugate of operator A	$A^\dagger$
momentum operator in coordinate representation	$+(h/2\pi i)\nabla$
annihilation operators	a, b, α, β
creation operators	$a^\dagger, b^\dagger, \alpha^\dagger, \beta^\dagger$

[*Note*: A, B or $A; B$ denote no preference; $A \ldots B$ denotes A preferred]

(*m*) Solid state physics

fundamental translations for lattice	$\boldsymbol{a}, \boldsymbol{b}, \boldsymbol{c}$; $\boldsymbol{a}_1, \boldsymbol{a}_2, \boldsymbol{a}_3$
Miller indices	$h, k, l; h_1, h_2, h_3$
plane in lattice (1)	$(h\,k\,l); (h_1\,h_2\,h_3)$
direction in lattice (1)	$[h\,k\,l]; [h_1\,h_2\,h_3]$
fundamental translations in reciprocal lattice	$\boldsymbol{a}^*, \boldsymbol{b}^*, \boldsymbol{c}^*$; $\boldsymbol{b}_1, \boldsymbol{b}_2, \boldsymbol{b}_3$
vector in crystal lattice	$\boldsymbol{r}$
distance between successive lattice planes	d
Bragg angle	θ
order of reflexion	n
short range order parameter	σ
long range order parameter	s
Burgers vector	$\boldsymbol{b}$
circular wave vector, propagation vector (of phonons)	$\boldsymbol{q}$

circular wave vector, propagation vector (of particles)	$\boldsymbol{k}$
effective mass of electron	m^*, m_{eff}
Fermi energy	E_F, ϵ_F
Fermi circular wave vector	$\boldsymbol{k}_F$
work function	$\mathit{\Phi}$
differential thermoelectric power	$S \ldots \mathit{\Sigma}$
Peltier coefficient	$\mathit{\Pi}$
Thomson coefficient	μ
piezoelectric coefficient (polarization/stress)	d_{mn}
characteristic (Weiss) temperature	$\mathit{\Theta}, \mathit{\Theta}_W$
Curie temperature	T_C
Néel temperature	T_N
Hall coefficient	R_H

(*n*) Molecular spectroscopy (2)

quantum number	
of component of electronic orbital angular momentum vector along symmetry axis	$\mathit{\Lambda}, \lambda_i$
of component of electronic spin along symmetry axis	$\mathit{\Sigma}, \sigma_i$
of total electronic angular momentum vector along symmetry axis	$\mathit{\Omega}, \omega_i$
of electronic spin	S
of nuclear spin	I
of vibrational mode	v
of vibrational angular momentum (linear molecules)	l
of total angular momentum (excluding nuclear spin)	J
of component of $\boldsymbol{J}$ in direction of external field	M, M_J
of component of $\boldsymbol{S}$ in direction of external field	M_S
of total angular momentum (including nuclear spin: $\boldsymbol{F} = \boldsymbol{J} + \boldsymbol{I}$)	F
of component of $\boldsymbol{F}$ in direction of external field	M_F
of component of $\boldsymbol{I}$ in direction of external field	M_I

(1) Braces { } and angle brackets ⟨ ⟩ are used to enclose symmetry-related sets (forms) of planes and directions respectively. Further details regarding crystallographic notation can be found in *International tables for X-ray crystallography*, vol. 1, published for the International Union of Crystallography (1965).

(2) Further details can be found in 'Report on notation for the spectra of polyatomic molecules' (Joint Commission for Spectroscopy of I.U.P.A.P. and I.A.U., 1954), *Journal of Chemical Physics* (1955) **23**, 1997.

[*Note*: A, B denotes no preference; $A \ldots B$ denotes A preferred]

of component of angular momentum along axis (linear and symmetric top molecules; excluding electron- and nuclear spin; for linear molecules $K = \lvert \Lambda + l \rvert$)	K
of total angular momentum (linear and symmetric top molecules; excluding electron- and nuclear spin: $\boldsymbol{J} = \boldsymbol{N} + \boldsymbol{S}$ (1))	N
of component of angular momentum along symmetry axis (linear and symmetric top molecules; excluding nuclear spin; for linear molecules: $P = \lvert K + \Sigma \rvert$ (2))	P
degeneracy of vibrational mode	d
electronic term: E_e/hc (3)	T_e
vibrational term: E_vib/hc	G
coefficients in expression for vibrational term for diatomic molecule: $G = \sigma_\mathrm{e}(v+\frac{1}{2}) - x\sigma_\mathrm{e}(v+\frac{1}{2})^2$	σ_e and $x\sigma_\mathrm{e}$
coefficients in expression for vibrational term for polyatomic molecule: $G = \Sigma_\mathrm{j}\sigma_\mathrm{j}(v_\mathrm{j} + \frac{1}{2}d_\mathrm{j}) + \frac{1}{2}\Sigma_\mathrm{j}\Sigma_\mathrm{k}x_\mathrm{jk}(v_\mathrm{j} + \frac{1}{2}d_\mathrm{j})(v_\mathrm{k} + \frac{1}{2}d_\mathrm{k})$	σ_j and x_jk
rotational term: E_rot/hc	F
moment of inertia of diatomic molecule	I
rotational constant of diatomic molecule: $h/8\pi^2 cI$	A
principal moments of inertia of polyatomic molecule ($I_\mathrm{A} \leqslant I_\mathrm{B} \leqslant I_\mathrm{C}$)	$I_\mathrm{A}, I_\mathrm{B}, I_\mathrm{C}$
rotational constants of polyatomic molecule: $A = h/8\pi^2 cI_\mathrm{A}$, etc.	A, B, C
total term: $T_\mathrm{e} + G + F$	T

I.2.13. *Mathematical operations on physical quantities*

Addition and subtraction of two physical quantities are indicated by

$$a+b \quad \text{and} \quad a-b$$

Multiplication of two (scalar (4)) physical quantities may be indicated in one of the following ways:

$$ab \quad a\,b \quad a.b \quad a \cdot b \quad a \times b$$

Division of one quantity by another quantity may be indicated in one of the following ways:

$$\frac{a}{b} \quad a/b \quad ab^{-1}$$

or in any of the other ways of writing the product of a and b^{-1}.

These procedures can be extended to cases where one of the quantities or both are themselves products, quotients, sums, or differences of other quantities.

Brackets should be used in accordance with the rules of mathematics. If the solidus is used to separate the numerator from the denominator and if there is any doubt where the numerator starts or where the denominator ends, brackets should be used.

Examples:

Expressions with a horizontal rule	Same expressions with a solidus
$\frac{a}{bcd}$	a/bcd
$\frac{2}{9}\sin kx, \ \frac{1}{2}RT$	$(2/9)\sin kx, \ RT/2$
$\frac{a}{b} - c$	$a/b - c$
$\frac{a}{b-c}$	$a/(b-c)$
$\frac{a-b}{c-d}$	$(a-b)/(c-d)$
$\frac{a}{c} - \frac{b}{d}$	$a/c - b/d$

Remark. It is recommended that in expressions like:

$$\sin\{2\pi(x-x_0)/\lambda\} \qquad \exp\{(r-r_0)/\sigma\}$$

$$\exp\{-V(r)/kT\} \qquad \surd(\epsilon/c^2)$$

the argument should always be placed between brackets, except when the argument is a simple product, for example: $\sin kx$, $\sin 2\pi\nu t$.

A list of recommended symbols for mathematical operators and mathematical constants will be found in Part II.

I.3. Units and symbols for units

I.3.1. *The International System of Units (Système International d'Unités-SI)*

The name International System of Units (SI) was adopted by the Conférence Générale des Poids et Mesures in 1960 for the coherent (1) system based on the units: metre, kilogramme, second, ampere, kelvin, and candela. In the International System there is one and only one basic unit for each physical quantity. Decimal fractions and multiples of these basic units may, however, be constructed by use of approved prefixes. A seventh unit, the mole, is defined below as the basic unit of amount of substance although it has not been formally adopted as an SI unit.

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(1) System of loosely coupled electrons.

(2) System of tightly coupled electrons.

(3) All energies are taken here with respect to the ground state as reference level.

(4) For vector quantities see p. 32.

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(1) A coherent system of units is a system based on a selected set of 'basic units' from which all 'derived units' are obtained by multiplication without introducing numerical factors. In addition there are 'dimensionless units', in particular the radian (symbol: rad) for plane angle and the steradian (symbol: sr) for solid angle.

I.3.2. *Definitions of the basic SI units*

Metre: The metre is the length equal to 1 650 763.73 wavelengths in vacuum of the radiation corresponding to the transition between the levels $2p_{10}$ and $5d_5$ of the krypton-86 atom.

Kilogramme: The kilogramme is the unit of mass; it is equal to the mass of the international prototype of the kilogramme.

Second: The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium-133 atom.

Ampere: The ampere is that constant current which, if maintained in two straight parallel conductors of infinite length, of negligible circular cross-section, and placed 1 metre apart in vacuum, would produce between these conductors a force equal to 2×10^{-7} newton per metre of length.

Kelvin: The kelvin, unit of thermodynamic temperature, is the fraction 1/273.16 of the thermodynamic temperature of the triple point of water.⁽¹⁾

Candela: The candela is the luminous intensity, in the perpendicular direction, of a surface of 1/600 000 square metre of a black body at the temperature of freezing platinum under a pressure of 101 325 newtons per square metre.

Mole: The mole is the amount of substance of a system which contains as many elementary units as there are carbon atoms in 0.012 kilogramme of carbon-12. The elementary unit must be specified and may be an atom, a molecule, an ion, an electron, a photon, etc., or a specified group of such entities.

Examples:

1 mole of HgCl has a mass equal to 0.236 04 kilogramme

1 mole of Hg_2Cl_2 has a mass equal to 0.472 08 kilogramme

1 mole of e^- has a mass equal to 5.4860×10^{-7} kilogramme

1 mole of a mixture containing $\frac{2}{3}$ mole of H_2 and $\frac{1}{3}$ mole of O_2 has a mass equal to 0.012 010 2 kilogramme.

---

(1) In October 1967 the thirteenth Conférence Générale des Poids et Mesures recommended that the kelvin, symbol K, be used both for thermodynamic temperature and for thermodynamic temperature interval, and that the unit-symbols °K and deg be abandoned. In accordance with this recommendation the symbol K has been used throughout this Report. However, until this symbol is generally accepted it is suggested that the traditional symbol °K be permitted when it is particularly requested.

I.3.3. *Names and symbols for basic SI units*

Physical quantity	Name of SI unit	Symbol for SI unit
length	metre	m
mass	kilogramme	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	kelvin	K
luminous intensity	candela	cd
amount of substance	mole	mol

I.3.4. *Names and symbols for supplementary units*

These units are dimensionless.

Physical quantity	Name of SI unit	Symbol for SI unit
plane angle	radian	rad
solid angle	steradian	sr

I.3.5. *Special names and symbols for derived SI units*

Physical quantity	Name of SI unit	Symbol for SI unit	Definition of SI unit
energy	joule	J	$kg\,m^2\,s^{-2}$
force	newton	N	$kg\,m\,s^{-2} = J\,m^{-1}$
power	watt	W	$kg\,m^2\,s^{-3} = J\,s^{-1}$
electric charge	coulomb	C	$A\,s$
electric potential difference	volt	V	$kg\,m^2\,s^{-3}\,A^{-1} = J\,A^{-1}\,s^{-1}$
electric resistance	ohm	Ω	$kg\,m^2\,s^{-3}\,A^{-2} = V\,A^{-1}$
electric capacitance	farad	F	$A^2\,s^4\,kg^{-1}\,m^{-2} = A\,s\,V^{-1}$
magnetic flux	weber	Wb	$kg\,m^2\,s^{-2}\,A^{-1} = V\,s$
inductance	henry	H	$kg\,m^2\,s^{-2}\,A^{-2} = V\,A^{-1}\,s$
magnetic flux density	tesla	T	$kg\,s^{-2}\,A^{-1} = V\,s\,m^{-2}$
luminous flux	lumen	lm	$cd\,sr$
illumination	lux	lx	$cd\,sr\,m^{-2}$
frequency	hertz	Hz	s^{-1}

I.3.6. *Derived SI units and unit symbols for other quantities*

(This list is merely illustrative)

Physical quantity	SI unit	Symbol for SI unit
area	square metre	$\mathrm{m^2}$
volume	cubic metre	$\mathrm{m^3}$
density	kilogramme per cubic metre	$\mathrm{kg\,m^{-3}}$
velocity	metre per second	$\mathrm{m\,s^{-1}}$
angular velocity	radian per second	$\mathrm{rad\,s^{-1}}$
acceleration	metre per second squared	$\mathrm{m\,s^{-2}}$
pressure	newton per square metre	$\mathrm{N\,m^{-2}}$
kinematic viscosity, diffusion coefficient	square metre per second	$\mathrm{m^2\,s^{-1}}$
dynamic viscosity	newton second per square metre	$\mathrm{N\,s\,m^{-2}}$
electric field strength	volt per metre	$\mathrm{V\,m^{-1}}$
magnetic field strength	ampere per metre	$\mathrm{A\,m^{-1}}$
luminance	candela per square metre	$\mathrm{cd\,m^{-2}}$

I.3.7. *Prefixes for SI units*

The following prefixes may be used to indicate decimal fractions or multiples of the basic (§I.3.3) or derived (§I.3.5) SI units.

Fraction	Prefix	Symbol	Multiple	Prefix	Symbol
10^{-1}	deci	d	10	deka	da
10^{-2}	centi	c	10^{2}	hecto	h
10^{-3}	milli	m	10^{3}	kilo	k
10^{-6}	micro	μ	10^{6}	mega	M
10^{-9}	nano	n	10^{9}	giga	G
10^{-12}	pico	p	10^{12}	tera	T
10^{-15}	femto	f			
10^{-18}	atto	a			

I.3.8. *Decimal fractions and multiples of SI units having special names*

These names are not part of the SI. It is recognized that their use may be continued for some time but it is recommended that except in special circumstances they should be progressively abandoned in conformity with international recommendations. The following list is not exhaustive.

Physical quantity	Name of unit	Symbol for unit	Definition of unit
length	ångström (1)	Å	$10^{-10}\,\mathrm{m} = 10^{-1}\,\mathrm{nm}$
length	micron (2)	μm	$10^{-6}\,\mathrm{m}$
area	barn	b	$10^{-28}\,\mathrm{m^2}$
volume	litre (3)	l	$10^{-3}\,\mathrm{m^3} = \mathrm{dm^3}$
mass	tonne	t	$10^{3}\,\mathrm{kg} = \mathrm{Mg}$
force	dyne	dyn	$10^{-5}\,\mathrm{N}$
pressure	bar	bar	$10^{5}\,\mathrm{N\,m^{-2}}$
pressure	pascal (4)	Pa (4)	$\mathrm{N\,m^{-2}}$
energy	erg	erg	$10^{-7}\,\mathrm{J}$
kinematic viscosity, diffusion coefficient	stokes	St	$10^{-4}\,\mathrm{m^2\,s^{-1}}$
dynamic viscosity	poise	P	$10^{-1}\,\mathrm{kg\,m^{-1}\,s^{-1}}$
magnetic flux	maxwell	Mx	$10^{-8}\,\mathrm{Wb}$
magnetic flux density (magnetic induction)	gauss	G	$10^{-4}\,\mathrm{T}$
conductance	siemens (4)	S (4)	Ω^{-1}

(1) It is understood that the Triple Commission of Spectroscopy (which has representatives from the International Astronomical Union, the International Union of Pure and Applied Physics, and the International Union of Pure and Applied Chemistry) is unanimously in favour of the continued use of the ångström.

(2) The symbol μ is still unfortunately used by some spectroscopists and biologists instead of μm, and likewise the symbol mμ, instead of the symbol nm.

(3) By decision of the twelfth Conférence Générale des Poids et Mesures in October 1964 the old definition of the litre (1.000 028 $\mathrm{dm^3}$) was rescinded and the word litre reinstated as a special name for the cubic decimetre. Neither the word litre nor its symbol l should be used to express results of high precision.

(4) The special names (and symbols) pascal (Pa) and siemens (S) are used for the derived SI units of pressure and conductance respectively. They appear here rather than in §I.3.5 because they have not been adopted as SI units by the Conférence Générale des Poids et Mesures.

I.3.9. *Other units now exactly defined in terms of the SI units*

These units are not part of the SI. It is recognized that their use may be continued for some time but it is recommended that except in special circumstances they should be progressively abandoned in conformity with international recommendations. The following list is by no means exhaustive. Each of the definitions given in the fourth column is *exact*.

Physical quantity	Name of unit	Symbol for unit	Definition of unit
length	inch	in	$2.54 \times 10^{-2}\,\mathrm{m}$
mass	pound (avoirdupois)	lb	$0.453\,592\,37\,\mathrm{kg}$
force	kilogramme-force	kgf	$9.806\,65\,\mathrm{N}$
pressure	atmosphere	atm	$101\,325\,\mathrm{N\,m^{-2}}$
pressure	torr	Torr	$(101\,325/760)\,\mathrm{N\,m^{-2}}$
pressure	conventional millimetre of mercury (1)	mmHg	$13.5951 \times 980.665 \times 10^{-2}\,\mathrm{N\,m^{-2}}$
energy	kilowatt hour	kW h	$3.6 \times 10^{6}\,\mathrm{J}$
energy	thermochemical calorie	cal(thermochem.)	$4.184\,\mathrm{J}$
energy	I.T. calorie	$\mathrm{cal_{IT}}$	$4.1868\,\mathrm{J}$
thermodynamic temperature (T)	degree Rankine (2)	°R	$(5/9)\,\mathrm{K}$
common temperature (t)	degree Celsius (2)	°C	$t/°\mathrm{C} = T/\mathrm{K} - 273.15$
common temperature (t)	degree Fahrenheit (2)	°F	$t/°\mathrm{F} = T/°\mathrm{R} - 459.67$
radioactivity	curie	Ci	$3.7 \times 10^{10}\,\mathrm{s^{-1}}$

(1) The conventional millimetre of mercury, symbol mmHg (not mm Hg), is the pressure exerted by a column exactly 1 mm high of a fluid of density exactly $13.5951\ \mathrm{g\,cm^{-3}}$ in a place where the gravitational acceleration is exactly $980.665\,\mathrm{cm\,s^{-2}}$. The difference between 1 mmHg and 1 Torr is less than 2×10^{-7} Torr.

(2) The ° sign and the letter following form one symbol and there should be no space between them. *Example*: 25 °C not 25° C.

I.3.10. *Units defined in terms of the best available experimental values of certain physical constants*

These units are not part of the SI. The factors for conversion of these units to SI units are subject to change in the light of new experimental measurements of the constants involved. Their use outside the restricted contexts to which they are appropriate should be discouraged. The following list is not exhaustive.

Physical quantity	Name of unit	Symbol for unit	Conversion factor
energy	electronvolt	eV	$\mathrm{eV} \approx 1.6021 \times 10^{-19}\,\mathrm{J}$
mass	unified atomic mass unit	u	$\mathrm{u} \approx 1.66041 \times 10^{-27}\,\mathrm{kg}$

I.3.11. *'International' electrical units*

These units are obsolete, having been replaced by the 'absolute' (SI) units in 1948. The conversion factors which should be used with electrical measurements quoted in 'international' units depend on where and when the instruments used to make the measurements were calibrated. The following two sets of conversion factors refer respectively to the 'mean international' units estimated by the ninth Conférence Générale des Poids et Mesures in 1948, and to the 'U.S. international' units estimated by the U.S. National Bureau of Standards as applying to instruments calibrated by them before 1948.

1 'mean international ohm' = 1.000 49 Ω

1 'mean international volt' = 1.000 34 V

1 'U.S. international ohm' = 1.000 495 Ω

1 'U.S. international volt' = 1.000 330 V

I.3.12. *Electrical and magnetic units belonging to unit-systems other than the SI*

Definitions of units used in the 'electrostatic CGS' and 'electromagnetic CGS' unit-systems can be found in the ISO document: *Quantities and units of electricity and magnetism* (1965, R 31, Part V, obtainable from the British Standards Institution), or in the I.U.P.A.P. document U.I.P. 11 (S.U.N. 65-3): '*Symbols, units and nomenclature in physics* (1965).

I.3.13. *Printing of symbols for units*

The symbol for a unit should be printed in roman (upright) type, should remain unaltered in the plural, and should not be followed by a full stop except when it occurs at the end of a sentence.

Example: 5 cm but not 5 cms. and not 5 cm. and not 5 cms

The symbol for a unit derived from a proper name should begin with a capital roman (upright) letter.

Examples: J for joule and Hz for hertz

Any other symbol for a unit should be printed in lower case roman (upright) type.

I.3.14. *Printing of prefixes*

Symbols for prefixes for units should be printed in roman (upright) type with no space between the prefix and the unit. Compound prefixes should not be used.

Example: ns but not mμs for 10^{-9} s

I.3.15. *Combination of prefix and symbol*

A combination of prefix and symbol for a unit is regarded as a single symbol which may be raised to a power without the use of brackets.

Example: cm^2 always means $(0.01\ \mathrm{m})^2$ and never $0.01\ \mathrm{m}^2$

I.3.16. *Multiplication and division of units*

A product of two units may be represented in any of the ways:

$$\mathrm{N\ m} \quad \text{or} \quad \mathrm{N \cdot m} \quad \text{or} \quad \mathrm{N.m} \quad \text{or} \quad \mathrm{N \times m}$$

The representation Nm is not recommended.

A quotient of two units may be represented in any of the ways:

$$\mathrm{m\ s^{-1}} \quad \text{or} \quad \mathrm{m/s} \quad \text{or} \quad \frac{\mathrm{m}}{\mathrm{s}}$$

or in any of the other ways of writing the product of m and s^{-1}.

These rules may be extended to more complex groupings but more than one solidus (/) should never be used in the same expression unless parentheses are used to eliminate ambiguity.

Examples: $\mathrm{J\ K^{-1}\,mol^{-1}}$ or J/K mol but not J/K/mol

$\mathrm{cm^2\,V^{-1}\,s^{-1}}$ but not cm/s/V/cm; $\mathrm{cm\,s^{-1}/V\,cm^{-1}}$ and (cm/s)/(V/cm) though algebraically correct are not to be encouraged.

I.4. Numbers

I.4.1. *Printing of numbers*

Numbers should be printed in upright type. The decimal sign between digits in a number should be a point (.) or a comma (,). To facilitate the reading of long numbers the digits may be grouped in threes about the decimal sign but no point or comma should ever be used except for the decimal sign.

Example: 2 573.421 736 but not 2,573.421,736

When the decimal sign is placed before the first digit of a number a zero should always be placed before the decimal sign.

Example: 0.2573×10^4 but not $.2573 \times 10^4$

It is often convenient to print numbers with just one digit before the decimal sign.

Example: 2.573×10^3

I.4.2. *Multiplication and division of numbers*

The multiplication sign between numbers should be a cross (×).

Example: 2.3×3.4

Division of one number by another may be indicated in any of the ways:

$$\tfrac{136}{273} \quad \text{or} \quad 136/273 \quad \text{or} \quad 136 \times (273)^{-1}$$

These rules may be extended to more complex groupings, but more than one solidus (/) should never be used in the same expression unless parentheses are used to eliminate ambiguity.

Example: (136/273)/2.303 or 136/(273 × 2.303) but never 136/273/2.303

PART II

RECOMMENDED MATHEMATICAL SYMBOLS

[*Note*: A, B denotes no preference; A…B denotes A preferred]

equal to	$=$	smaller than	$<$
not equal to	$\neq$	larger than	$>$
identically equal to	$\equiv$	smaller than or equal to	$\leqslant$
corresponds to	$\triangleq$	larger than or equal to	$\geqslant$
approximately equal to	$\approx$	much smaller than	$\ll$
approaches	$\rightarrow$	much larger than	$\gg$
asymptotically equal to	$\simeq$	plus	$+$
proportional to	$\propto$	minus	$-$
infinity	∞	plus or minus	$\pm$
		minus or plus	$\mp$

a multiplied by b (1)	$ab,\ a.b,\ a\cdot b,\ a\times b$
a divided by b (1)	$a/b,\ \frac{a}{b},\ ab^{-1}$
magnitude of a	$\lvert a\rvert$
a raised to power n	a^n
square root of a	$a^{\frac{1}{2}},\ \sqrt{a}$
nth root of a	$a^{1/n},\ a^{\frac{1}{n}},\ \sqrt[n]{a}$
mean value of a	$\langle a\rangle,\ \bar{a}$
factorial p (2)	$p!$
binomial coefficient (3)	$\binom{n}{p}$

When letters of the alphabet are used to form mathematical operators (examples: d, Δ, ln, exp) or as mathematical constants (examples: e, π) they should be printed in roman (upright) type so as to distinguish them from the symbols for physical quantities which should be printed in italic (sloping) type

sum	Σ
product	Π
function of x	$f(x),\ \mathrm{f}(x)$
limit to which $f(x)$ tends as x approaches a	$\lim\limits_{x\to a} f(x),\ \lim_{x\to a} f(x)$

---

(1) See also §I.2.13.

(2) $p! = 1\times 2\times 3\times \ldots \times (p-1)\times p$ where p is a positive integer.

(3) $\binom{n}{p} = n!/(n-p)!\,p!$ where n and p are positive integers and $n \geqslant p$ and where $0! = 1$.

[Note: A, B denotes no preference; A…B denotes A preferred]

finite increment of x	Δx
variation of x	δx
differential coefficient of $f(x)$ with respect to x	$\frac{\mathrm{d}f}{\mathrm{d}x},\ \mathrm{d}f/\mathrm{d}x,\ f'(x)$
differential coefficient of order n of $f(x)$	$\frac{\mathrm{d}^{\mathrm{n}}f}{\mathrm{d}x^{\mathrm{n}}},\ \mathrm{d}^{\mathrm{n}}f/\mathrm{d}x^{\mathrm{n}},\ f^{(\mathrm{n})}(x)$
partial differential coefficient of $f(x, y, \ldots)$ with respect to x when $y, \ldots$ are held constant	$\frac{\partial f(x,y,\ldots)}{\partial x},\ \left(\frac{\partial f}{\partial x}\right)_y,\ (\partial f/\partial x)_y$
operator $\frac{\partial}{\partial x}$ or with single variable $\frac{\mathrm{d}}{\mathrm{d}x}$	D
the total differential of f	$\mathrm{d}f$
indefinite integral of $f(x)$ with respect to x	$\int f(x)\,\mathrm{d}x$
definite integral of $f(x)$ from $x = a$ to $x = b$	$\int_a^b f(x)\,\mathrm{d}x$
integral of $f(x)$ with respect to x round a closed contour	$\oint f(x)\,\mathrm{d}x$
exponential of x	$\exp x,\ \mathrm{e}^x$
base of natural logarithms	e
logarithm to the base a of x	$\log_a x$
natural logarithm of x	$\ln x,\ \log_{\mathrm{e}} x$
common logarithm of x	$\lg x,\ \log_{10} x \ldots \log x$
binary logarithm of x	$\mathrm{lb}\, x,\ \log_2 x$
ratio of circumference to diameter of a circle	π
sine of x	$\sin x$
cosine of x	$\cos x$
tangent of x	$\tan x$
cotangent of x	$\cot x$
secant of x	$\sec x$
cosecant of x	$\mathrm{cosec}\, x$
inverse sine of x	$\arcsin x \ldots \sin^{-1} x$
inverse cosine of x	$\arccos x \ldots \cos^{-1} x$
inverse tangent of x	$\arctan x \ldots \tan^{-1} x$
inverse cotangent of x	$\mathrm{arccot}\, x \ldots \cot^{-1} x$
inverse secant of x	$\mathrm{arcsec}\, x \ldots \sec^{-1} x$
inverse cosecant of x	$\mathrm{arccosec}\, x \ldots \mathrm{cosec}^{-1} x$
hyperbolic sine of x	$\sinh x$
hyperbolic cosine of x	$\cosh x$
hyperbolic tangent of x	$\tanh x$
hyperbolic cotangent of x	$\coth x$
hyperbolic secant of x	$\mathrm{sech}\, x$

hyperbolic cosecant of x	$\operatorname{cosech} x$
inverse hyperbolic sine of x	$\operatorname{arsinh} x \ldots \sinh^{-1} x$
inverse hyperbolic cosine of x	$\operatorname{arcosh} x \ldots \cosh^{-1} x$
inverse hyperbolic tangent of x	$\operatorname{artanh} x \ldots \tanh^{-1} x$
inverse hyperbolic cotangent of x	$\operatorname{arcoth} x \ldots \coth^{-1} x$
inverse hyperbolic secant of x	$\operatorname{arsech} x \ldots \operatorname{sech}^{-1} x$
inverse hyperbolic cosecant of x	$\operatorname{arcosech} x \ldots \operatorname{cosech}^{-1} x$

complex operator: $\mathrm{i}^2 + 1 = 0$	i, j
real part of z	$\operatorname{Re} z$
imaginary part of z	$\operatorname{Im} z$
modulus of z	$\lvert z \rvert$
argument of z	$\arg z$
complex conjugate of z	z^*

transpose of matrix A	$\tilde{A}$
complex conjugate matrix of matrix A	A^*
Hermitian conjugate matrix of matrix A	$A^\dagger$

vector	$\boldsymbol{A} \ldots \vec{A}$
magnitude of vector $\boldsymbol{A}$	$\lvert A \rvert, A$
scalar product of vectors $\boldsymbol{A}$ and $\boldsymbol{B}$	$\boldsymbol{A} \cdot \boldsymbol{B}, \boldsymbol{A} . \boldsymbol{B}$
vector product of vectors $\boldsymbol{A}$ and $\boldsymbol{B}$	$\boldsymbol{A} \times \boldsymbol{B}, \boldsymbol{A} \wedge \boldsymbol{B}$
dyadic product of vectors $\boldsymbol{A}$ and $\boldsymbol{B}$	$\boldsymbol{AB}$
differential vector operator	$\nabla, \dfrac{\partial}{\partial \boldsymbol{r}}$
gradient of ϕ	$\operatorname{grad} \phi, \nabla \phi$
divergence of $\boldsymbol{A}$	$\nabla \cdot \boldsymbol{A}, \operatorname{div} \boldsymbol{A}$
curl of $\boldsymbol{A}$	$\nabla \times \boldsymbol{A}, \nabla \wedge \boldsymbol{A}, \operatorname{curl} \boldsymbol{A}, \operatorname{rot} \boldsymbol{A}$
Laplacian of ϕ	$\nabla^2 \phi$
d'Alembertian of ϕ	$\Box \phi$

scalar product of tensors $\boldsymbol{S}$ and $\boldsymbol{T}$	$\boldsymbol{S} : \boldsymbol{T}$
tensor product of tensors $\boldsymbol{S}$ and $\boldsymbol{T}$	$\boldsymbol{S} \cdot \boldsymbol{T}, \boldsymbol{S} . \boldsymbol{T}$
product of tensor $\boldsymbol{S}$ and vector $\boldsymbol{A}$	$\boldsymbol{S} \cdot \boldsymbol{A}, \boldsymbol{S} . \boldsymbol{A}$

Note. Mathematicians use many other symbols. An extensive list of such symbols is contained in *The mathematician and the printer*, by R. G. Hitchings, published by C. F. Hodgson & Son, Ltd, 23 Pakenham Street, London, W.C. 1 in 1964.

PART III

CHEMICAL ELEMENTS, NUCLIDES, AND PARTICLES

III.1. *Definitions*

A nuclide is a species of atoms identical as regards atomic number (proton number) and mass number (nucleon number). Two or more nuclides having the same atomic number but different mass numbers are called isotopes or isotopic nuclides. Two or more nuclides having the same mass number are called isobars or isobaric nuclides.

III.2. *Symbols for elements and nuclides*

Symbols for chemical elements should be written in roman type. The symbol is not followed by a full stop.

Examples: Ca, C, H, He

The attached numerals specifying a nuclide are as follows:

$$^{\text{mass number }14}\mathrm{N}_{2\text{ atoms/molecule}}$$

The atomic number may be placed in the left subscript position.

The right superscript position should be used, when required, to indicate states of ionization, excitation, or valency.

Examples:

Ionized states: Cl^-, SO_4^{2-}, Ca^{2+}, PO_4^{3-}
Electronic excited states: He^*, NO^*
Nuclear excited states: $^{110}\mathrm{Ag}^*$, $^{110}\mathrm{Ag}^{\mathrm{m}}$
Valence states: $\mathrm{K}_6\mathrm{M}^{\mathrm{IV}}\mathrm{Mo}_9\mathrm{O}_{32}$

III.3. *Symbols for particles and quanta*

neutron	n	pion	π
proton	p	muon	μ
deuteron	d	electron	e
triton	t	neutrino	ν
α-particle	α	photon	γ

It is recommended that the following notation should be used:

Hyperons: Upright capital greek letters to indicate specific particles, e.g. Λ, Σ.

Nucleons: Upright lower case n and p to indicate neutron and proton respectively.

Mesons: Upright lower case greek letters to indicate specific particles, e.g. π, μ, τ.

Leptons: L-particles; e.g. e, ν.

It is recommended that the charge of particles be indicated by adding the superscript +, −, or 0.

Examples:

$$\pi^+,\ \pi^-,\ \pi^0;\quad \mathrm{p}^+,\ \mathrm{p}^-;\ \mathrm{e}^+,\ \mathrm{e}^-.$$

If in connexion with the symbols p and e no charge is indicated, these symbols should refer to the positive proton and the negative electron respectively.

The symbol ~ above the symbol of a particle has been used to indicate the anti-particle of that particle (e.g. $\tilde{\nu}$ for anti-neutrino) and it is recommended that the same indication be used when needed in other cases.

III.4. *Notation for nuclear reactions*

The meaning of the symbolic expression indicating a nuclear reaction should be the following:

$$\begin{array}{l}\text{initial}\\ \text{nuclide}\end{array}\left(\begin{array}{l}\text{incoming particle(s)},\\ \text{or quanta}\end{array}\quad \begin{array}{l}\text{outgoing particle(s)}\\ \text{or quanta}\end{array}\right)\begin{array}{l}\text{final}\\ \text{nuclide}\end{array}$$

Examples:

$$^{14}\mathrm{N}(\alpha,\mathrm{p})^{17}\mathrm{O}\qquad ^{59}\mathrm{Co}(\mathrm{n},\gamma)^{60}\mathrm{Co}$$

$$^{23}\mathrm{Na}(\gamma,3\mathrm{n})^{20}\mathrm{Na}\qquad ^{31}\mathrm{P}(\gamma,\mathrm{pn})^{29}\mathrm{Si}$$

PART IV

QUANTUM STATES

IV.1. *General rules*

A letter symbol indicating the quantum state of *a system* should be printed in capital upright type. A letter symbol indicating the quantum state of *a single electron* should be printed in lower case upright type.

IV.2. *Atomic spectroscopy*

The letter symbols indicating quantum states are:

$$\begin{array}{lll}
L, l = 0: \mathrm{S,s} & L, l = 4: \mathrm{G,g} & L, l = 8: \mathrm{L,l}\\
\quad\ \ = 1: \mathrm{P,p} & \quad\ \ = 5: \mathrm{H,h} & \quad\ \ = 9: \mathrm{M,m}\\
\quad\ \ = 2: \mathrm{D,d} & \quad\ \ = 6: \mathrm{I,i} & \quad\ \ = 10: \mathrm{N,n}\\
\quad\ \ = 3: \mathrm{F,f} & \quad\ \ = 7: \mathrm{K,k} & \quad\ \ = 11: \mathrm{O,o}
\end{array}$$

A right hand subscript indicates the total angular momentum quantum number J or j. A left hand superscript indicates the spin multiplicity $2S+1$.

Examples: $^2\mathrm{P}_{\frac{3}{2}}$ - state ($J = \frac{3}{2}$, multiplicity 2)

$\mathrm{p}_{\frac{3}{2}}$ - electron ($j = \frac{3}{2}$)

An atomic electron configuration is indicated symbolically by:

$$(nl)^{\kappa}\,(n'l')^{\kappa'}\ldots.$$

The quantum symbols s, p, d, f, ... are used instead of $l = 0, 1, 2, 3, \ldots$.

Example: the atomic configuration: $(1\mathrm{s})^2\,(2\mathrm{s})^2\,(2\mathrm{p})^3$

IV.3. *Molecular spectroscopy*

The letter symbols indicating molecular electronic quantum states are for *linear molecules*:

$$\begin{array}{l}\Lambda, \lambda = 0: \Sigma, \sigma\\ \qquad\ \ = 1: \Pi, \pi\\ \qquad\ \ = 2: \Delta, \delta\end{array}$$

and for *non-linear molecules*:

A, a; B, b; E, e; etc.

A left hand superscript indicates the spin multiplicity. For molecules having a symmetry centre the parity symbol g or u, indicating respectively symmetric or antisymmetric behaviour on inversion, is attached as a right hand subscript. A + or − sign attached as a right hand superscript indicates the symmetry as regards reflexion in any plane through the symmetry axis of the molecules.

Examples: Σ_g^+, Π_u, $^2\Sigma$, $^3\Pi$, etc.

The letter symbols indicating the vibrational angular momentum states in the case of *linear molecules* are:

$l = 0$: Σ
$= 1$: Π
$= 2$: Δ

IV.4. *Nuclear spectroscopy*

The spin and parity assignment of a nuclear state is

$$J^\pi$$

where the parity symbol π is + for even and − for odd parity.

Examples:

$$3^+, 2^-, \text{etc.}$$

A shell model configuration is indicated symbolically by:

$$(n\,l\,j)^\kappa\,(n'l'j')^{\kappa'}$$

where the first bracket refers to the proton shell and the second to the neutron shell. Negative values of κ or κ' indicate holes in a completed shell. Instead of $l = 0, 1, 2, 3, \ldots$ the quantum state symbols s, p, d, f, ... are used.

Example:

The nuclear configuration $(1\,\mathrm{d}\,\frac{3}{2})^3\,(1\,\mathrm{f}\,\frac{7}{2})^2$.

IV.5. *Spectroscopic transitions*

The upper level and the lower level are indicated by ′ and ″ respectively.

Examples:

$$h\nu = E' - E'' \qquad \sigma = T' - T''$$

A spectroscopic transition should be indicated by writing the upper state first and the lower state second, connected by a dash in between.

Examples:

$^2\mathrm{P}_{\frac{1}{2}}$—$^2\mathrm{S}_{\frac{1}{2}}$	for an electronic transition
(J', K')—(J'', K'')	for a rotational transition
v'—v''	for a vibrational transition

Absorption transition and emission transition may be indicated respectively by arrows ← and →.

Examples:

$(J', K') \leftarrow (J'', K'')$	absorption from (J'', K'') to (J', K')
$^2\mathrm{P}_{\frac{1}{2}} \rightarrow {}^2\mathrm{S}_{\frac{1}{2}}$	emission from $^2\mathrm{P}_{\frac{1}{2}}$ to $^2\mathrm{S}_{\frac{1}{2}}$

The difference Δ between two quantum numbers should be that of the upper state minus that of the lower state.

Example:

$$\Delta J = J' - J''$$

The indications of the branches of the rotation band should be as follows:

$\Delta J = J' - J'' = -2$: O-branch
$= -1$: P-branch
$= 0$: Q-branch
$= +1$: R-branch
$= +2$: S-branch